2001 Mars Settlement Design Competition, NASA White Sands Test Facility, Las Cruces, NM.
November 9,10,11th, 2001

The Mars Settlement Design Competition is a program for high school students and teachers to experience the process of mission and hardware design. It provides a top level view into how NASA plans to explore space. I will be involved with all three days of this competition. On Friday I plan to give two presentations, one to the employees of White Sands Test Facility and one to students and teachers. On Saturday, I will have a question and answer session with some of the teachers participating in the workshop. Sunday I will serve as one of the judges that will review the students projects created over the weekend.

The main emphasis of my talk will focus on exploring the possibilities of the future of space exploration. I will discuss the Mars Reference Mission 3.0, as well as some of the current robotic missions being sent to Mars. Next, I will present a business model perfected by Hum Mandell, showing how the public, private, and commercial sectors all play a major role in sending humans to Mars. I will also discuss the work of the Integrated Design Team at JSC and how that working together approach is key for a successful design. Finally, I will present that the question of how humans can reach out beyond low earth orbit and place permanent settlements on Mars is really a function of the imagination of those who intend on going there.

Plans and Considerations for the Exploration of Space

November 9, 2001

Brian J. Derkowski

NASA Johnson Space Center

Advanced Design Team

Advanced Development Office

What Does The Future Hold?

- *There Are Many Possible Scenarios*
  - **No Future Human Exploration Past Space Station, All Exploration Robotic**
  - **Humans In Low Earth Orbit, Robots To The Planets**
  - **Humans To "Earth's Neighborhood," Continued Robotics To Planets**
  - **Humans Develop Colonies On Moon And Mars**
  - **Combinations Of The Above**
- *You Here Today Can Influence Which Path Is Taken*

"As for the future, your task is not to foresee it, but to enable it"

Antoine de Saint-Exupery

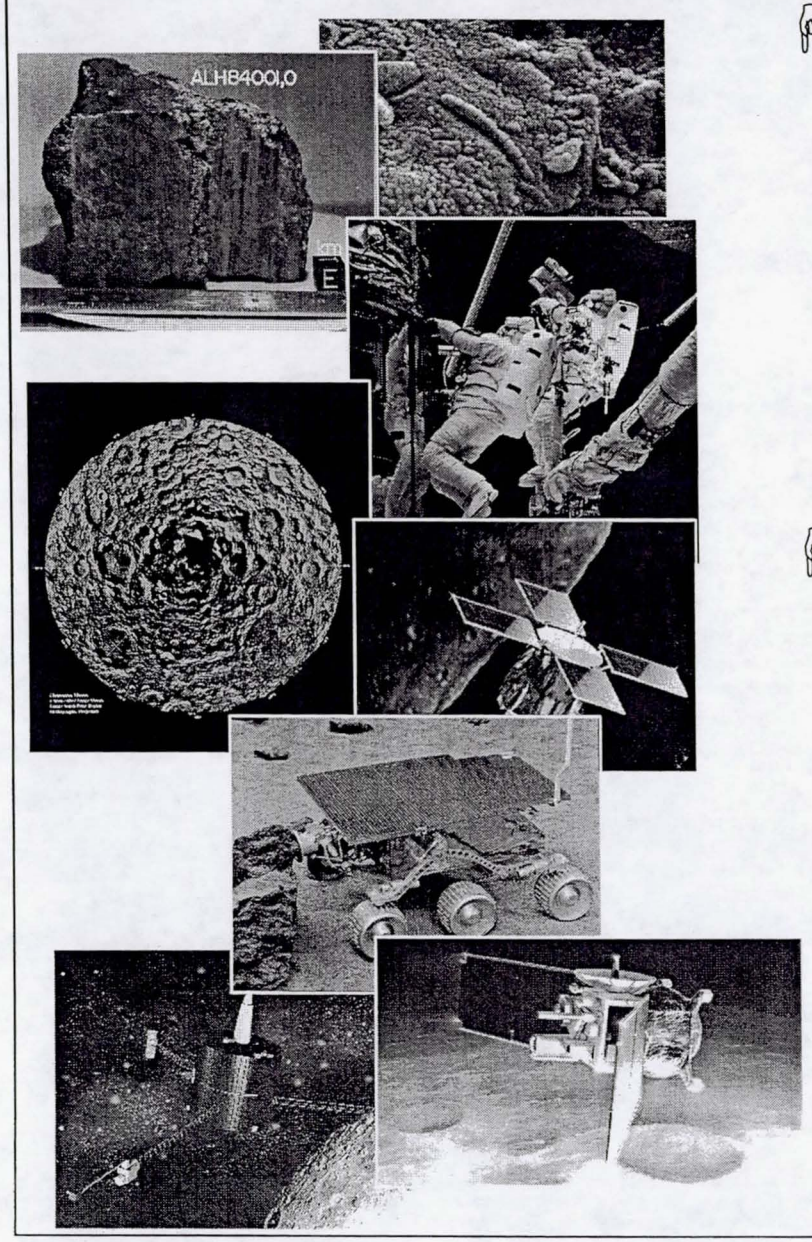
Clues to the Future

- ***No One Can Predict What the Future Holds***
- ***But We Can Look At Clues:***
  - What are the Motivations? Reasons?
  - What are the Opportunities? Markets?
  - What are the Challenges? Competition, Politics?
  - What are the Possible Destinations?
  - What Technologies Are Available? Resources?
  - What Architectures Are Best? How do We Package It To Sell to Our Customers?

Why Do We Go To Space?

- ***TO IMPROVE OUR LIVES ON EARTH !***
- ***To Pursue our Destiny: Space Exploration***
- ***To Discover:***
  - To Understand Ourselves and Our Place In the Universe
  - Looking Outward: Space Sciences, Search for Life (and Extraterrestrial Intelligence)
  - Looking Inward: Space Life Sciences
- ***To Make Profit: Commercial Space***
- ***To Defend our Nations: Space Security***
  - From Beyond
  - From Ourselves
- ***To Insure Survival of the Human Species:***
  - Save the Earth: Earth/Space Sustainability
  - Space Settlements

Opportunities and Challenges



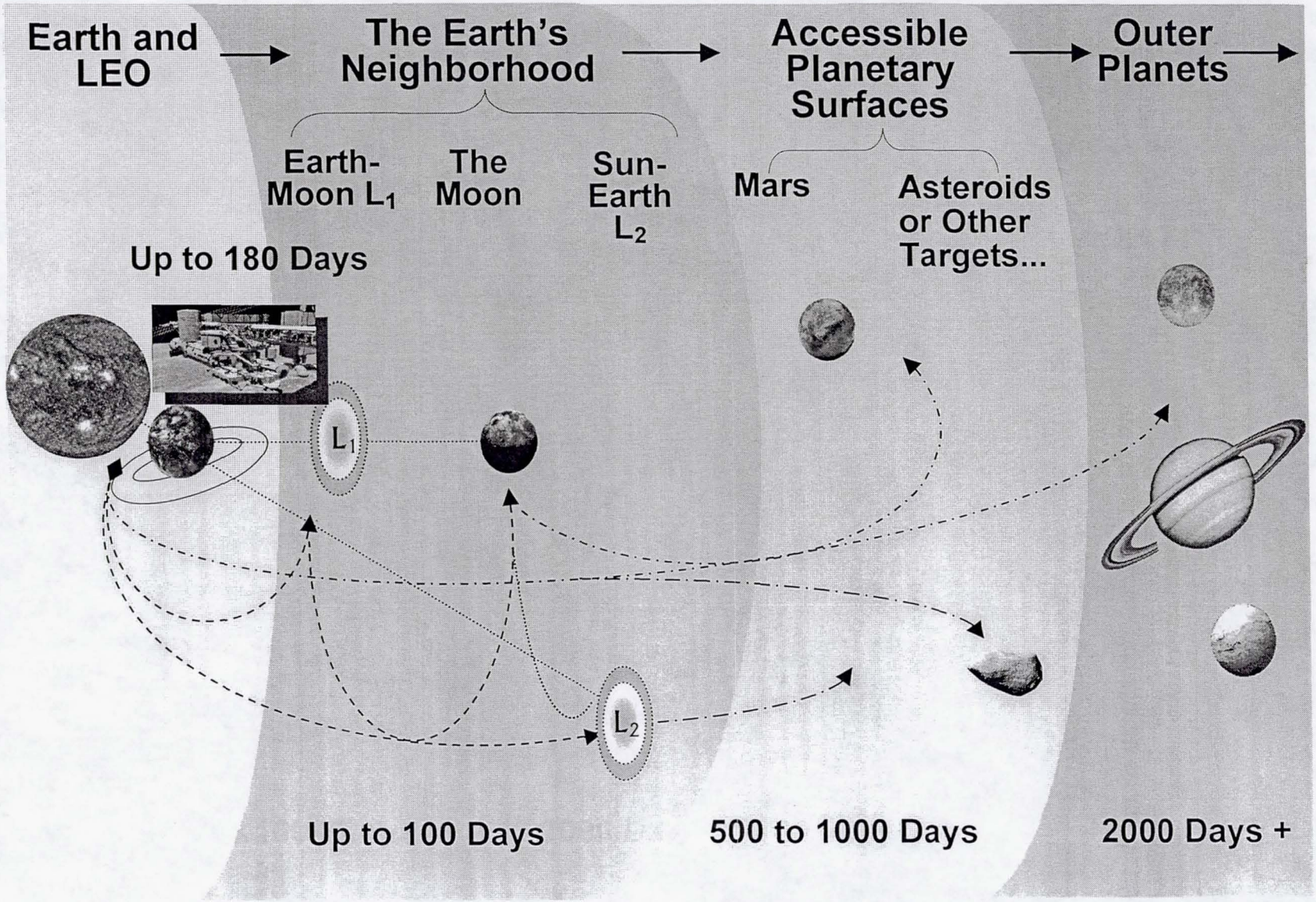
The Opportunity Window

- Allan Hills Meteorite
- Pathfinder
- Clementine
- Lunar Prospector
- Mars Global Surveyor
- NEAR
- New Viking Data Findings

The Challenges – Getting Permission From Our Customers

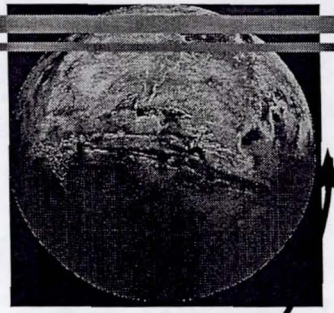
- Significant Reduction in Total Cost, Peak Annual Funding
- Low Cost Technologies, Commercial Systems
- Low Cost Architectures
- Involvement of Customers in the Excitement, the Experience

Where Can We Go? (NASA's Human Exploration and Development of Space Strategic Plan)



Where Should We Go First?
Earth's Neighborhood

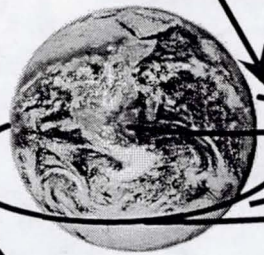
Mars



Space Station
Orbit (LEO)

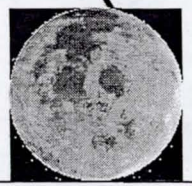
Mars
Aerocapture

Earth



Near Earth
Asteroids

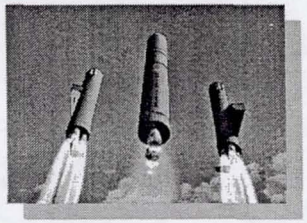
Moon



Libration
Points

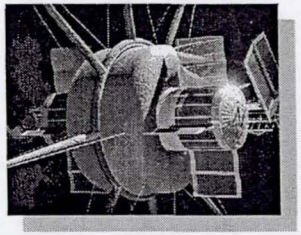
What Technologies Do We Need?

Earth to Orbit Transportation



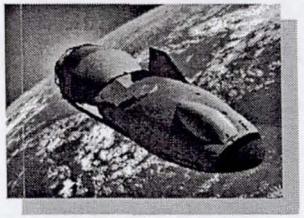
- Moon (follow on)
- Asteroids
- Mars

Interplanetary Habitation



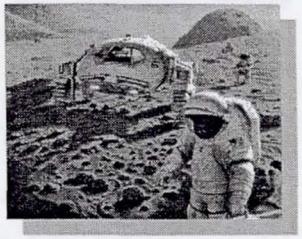
- Moon
- Sun-Earth Libration
- Asteroids
- Mars

Crew Taxi / Return



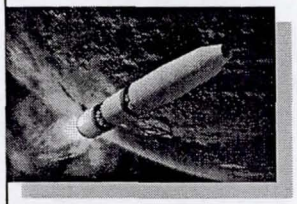
- Moon
- Sun-Earth Libration
- Asteroids
- Mars

EVA & Surface Mobility



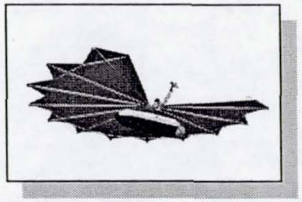
- Moon
- Mars
- Asteroids

Advanced Space Transportation Options



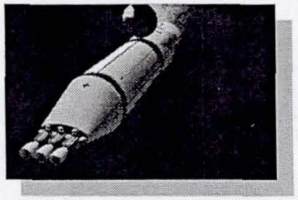
Advanced Chemical
"Small"
- Moon (follow on)
- Sun-Earth Libration

"Large"
- Asteroids
- Mars



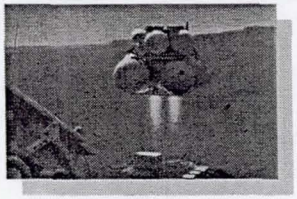
Electric Propulsion
<500 kWe
- Moon
- Sun-Earth Libration
- Mars Outpost

>1 MWe
- Asteroids
- Mars



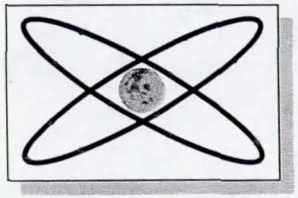
Nuclear Thermal
- Asteroids
- Mars
- Moon (follow-on)

In-Situ Resource Utilization



- Moon
- Mars

Com/Nav Infrastructure

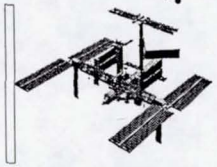


- Moon
- Mars

Packaging it For the Customer

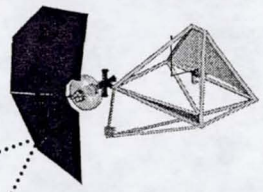
The Gateway Architecture

Cargo (Human Support, Science Support, Mars Transit Vehicle, Lunar Support

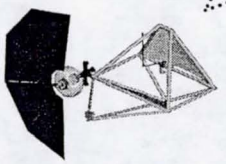


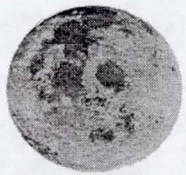
People (Round-Trip 10 Days)

Telescopes Deployed to Observing Position, Returned for Servicing



Earth-Sun L_2





Moon

Earth-Moon L_1 "Gateway"

- Science Instrument Assembly,Servicing
- Lunar Staging Facility
- Mars Vehicle Staging
- Opportunistic Deep-Space Biology

Mars

High-Thrust (People)

Low-Thrust (Cargo)

People To Mars?

- **There Are People Alive Today Who Can Visit Mars**
- **We Have the Technologies (In Hand or In Work)**
- **We Have Enough Money (If World Space Budgets Continue At Current Levels)**
- **We Can Be There In 7 Years From When We Get Permission To Go!**

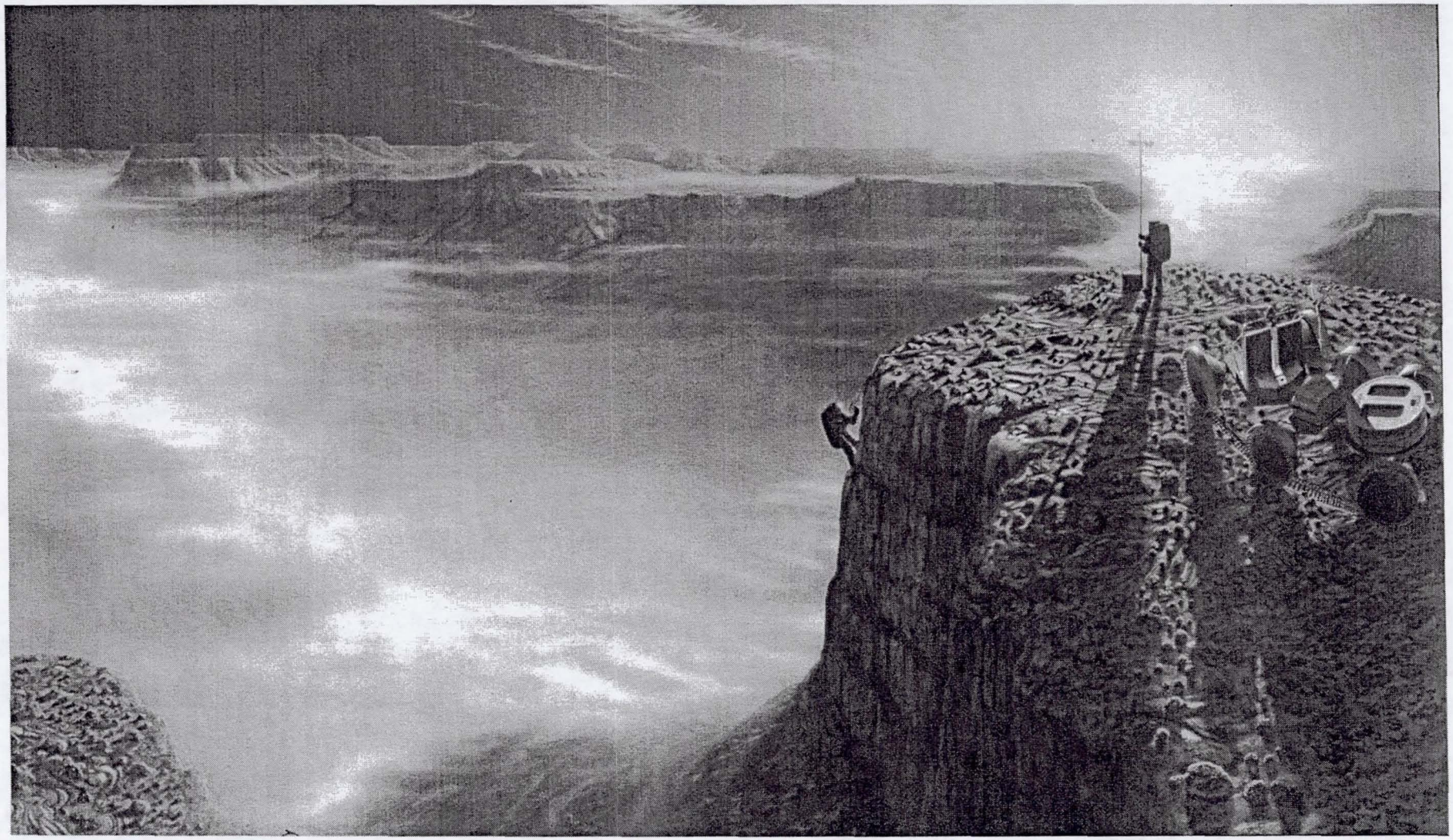
Why Don't we Have Permission?

What Have We Learned About Our Customers?

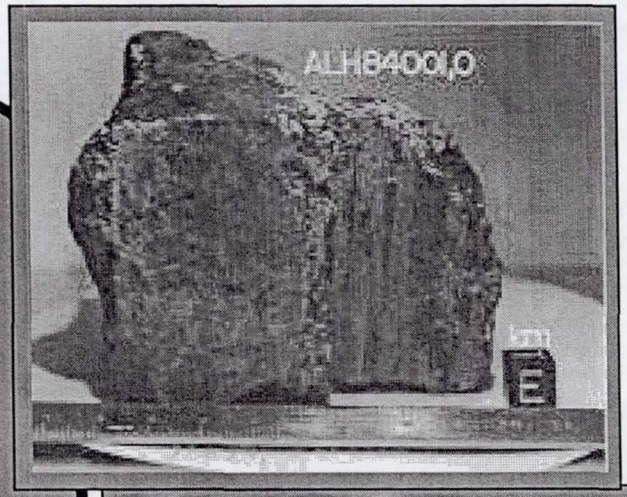
Mars Study History

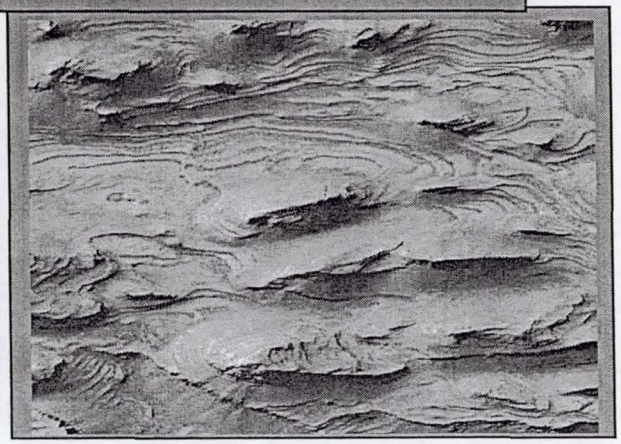
- ***NASA Has Been Studying Human Mars Missions Since the Early 1960's***
- ***The Space Exploration Initiative (SEI)***
  - 1989 US Presidential Commitment to go "Back to the Moon" and then to Mars
  - Victim of Presidential/Congressional Politics
  - And High Costs
- ***Costs Were Always Far Too High***
  - Low National Priority, Huge National Debt
  - Doubling, Tripling of NASA Budget Required
  - NASA Concern With Image of "Buying In"
- ***When Humans Go to Mars, it will Not be Done Like "Apollo"***
  - The Entire Political Scene Has Changed
  - Customer Permission, Engagement Is the Key
  - International Community and Private Sector Involvement / Leadership Is Essential

Why Do We Want to Go to Mars?



Why Scientists Want to Explore Mars





- 1996: Discovery of possible microfossil in Mars meteorite recovered in Antarctica energized Mars exploration
- Now focused on search for evidence of life (past and present)
- "Follow the Water" Strategy
- Comparative planetology

Why Is Water So Important?

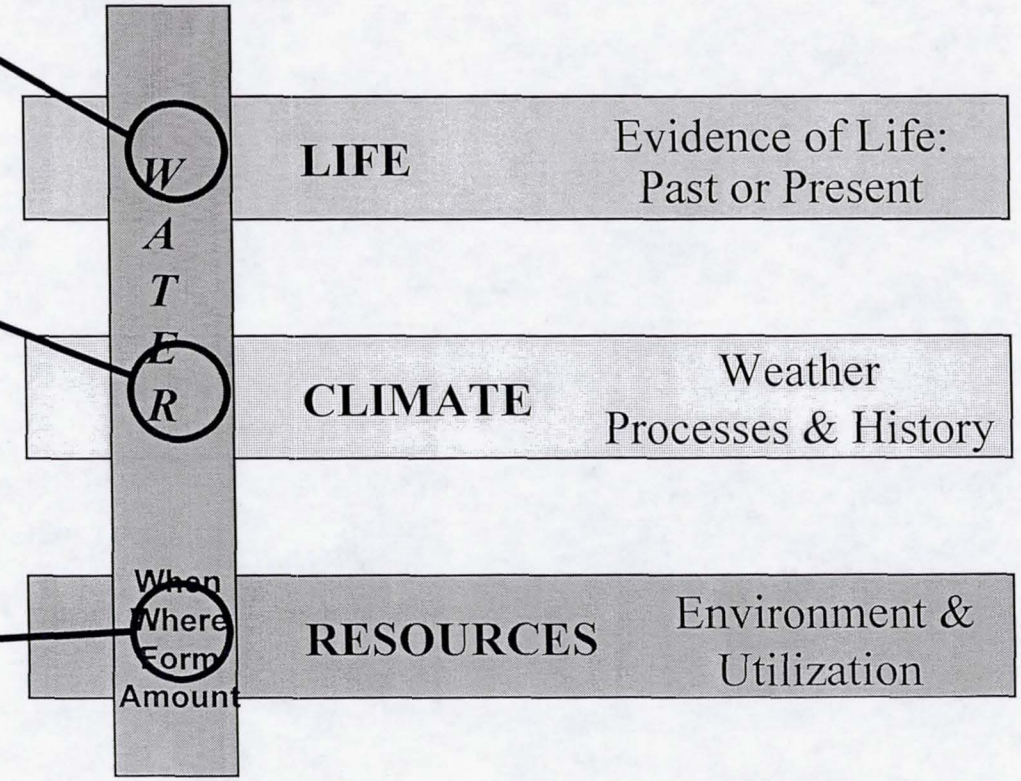
Mars Subsurface Exploration

Following the Water

Subsurface liquid water best chance of finding Martian life

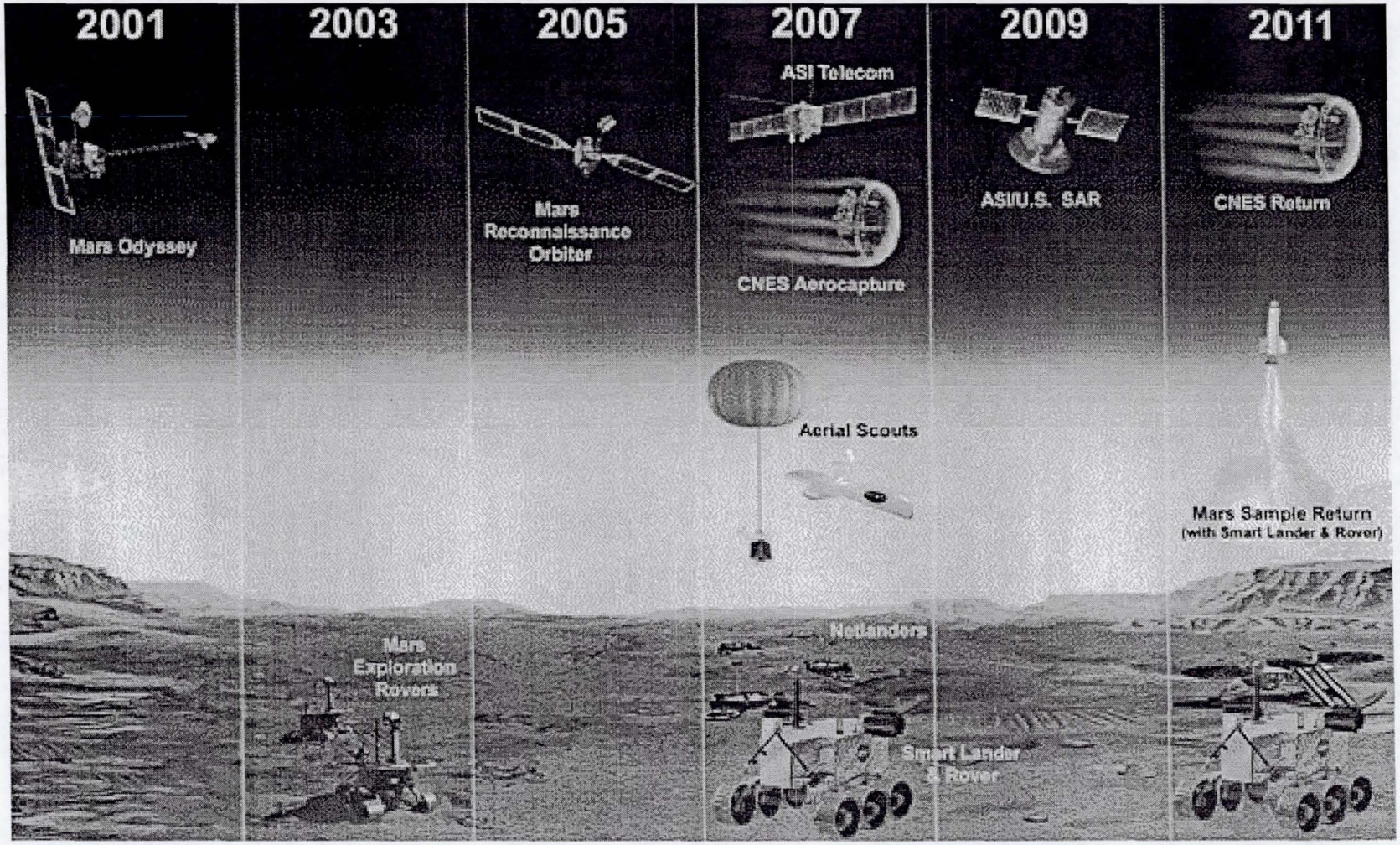
Cycling between subsurface and atmosphere: examine sedimentary record

Water is critical resource for HEDS and permanent Mars presence



How Will We Find the Water?

Mars Exploration : The Next Decade



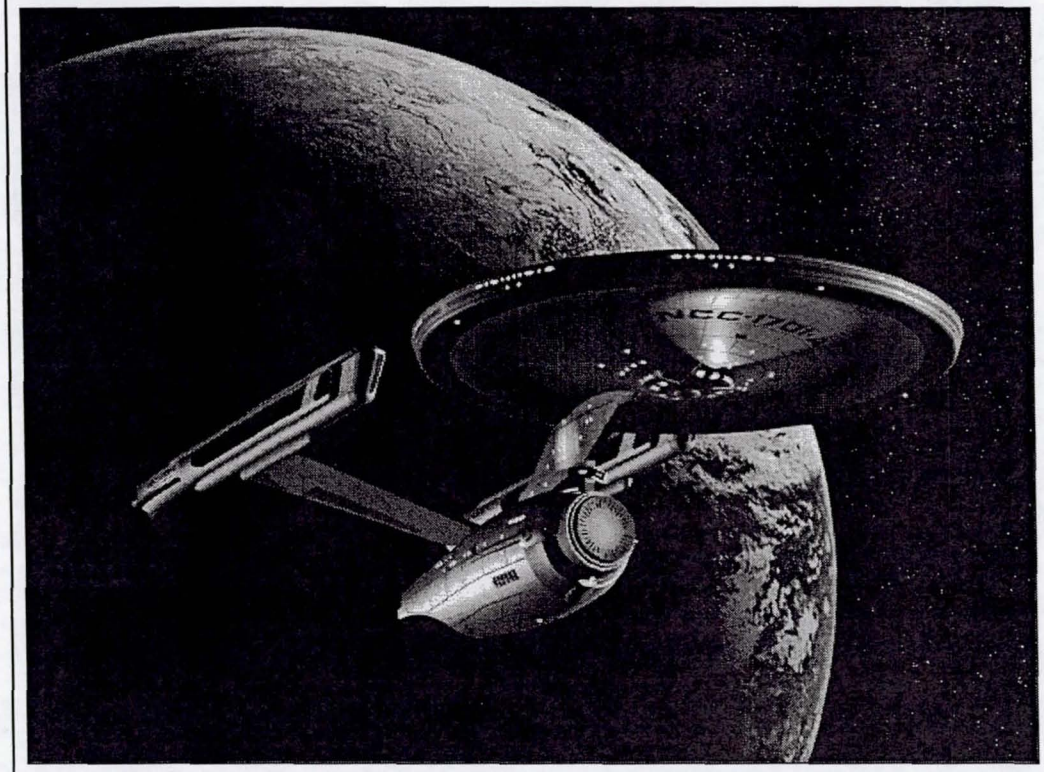
SO, WHAT'S STOPPING US
FROM SENDING HUMANS?

- ***We Don't Have "Permission" Yet***
  - **Public Perceptions**
    - **Prohibitive Costs**
    - **Size Of Space Budgets**
    - **Relative Priorities**
  - **High Costs**
  - **Customers' Priorities For Money**

How Do We Sell This to Our Customers?

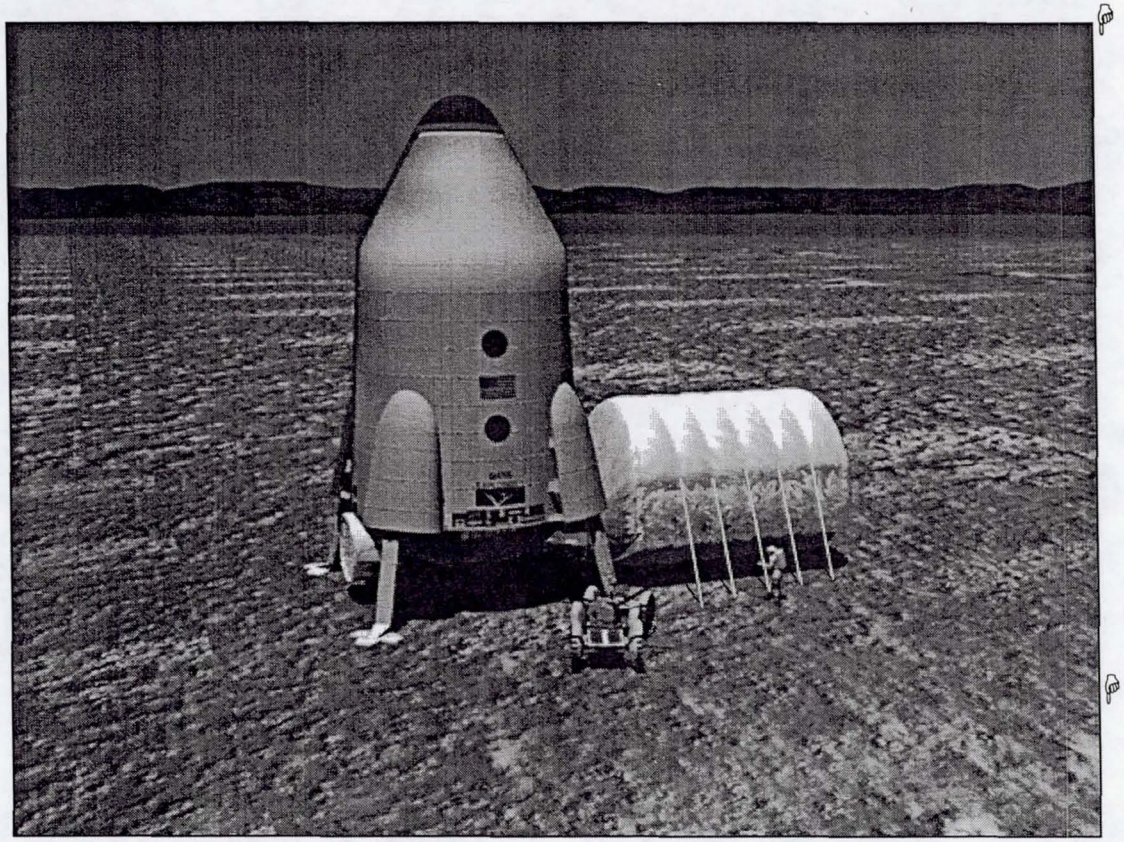
How Do We Lower the Costs?

Mars Mission Strategies - Old Way



- **Most past Mars studies employ "Starship Enterprise" approach**
  - Large "mother ship" constructed in Earth orbit, travels to and from Mars orbit
  - Crew takes "shuttlecraft" to surface and explores for a short time
  - If problems occur, abort to Earth
- **Basically incompatible with economical space flight and Mars mission objectives**
  - "Mother ship" requires huge propellant quantities or exotic propulsion technology
  - Complex and risky construction and integration in Earth orbit
  - Short surface stay limits mission objectives
  - "Abort to Earth" implies long duration interplanetary flight times

The Right Way: Living Off the Land

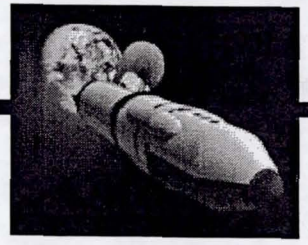


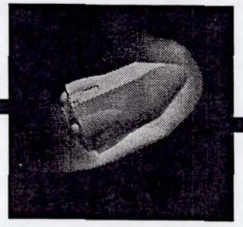
- **Shift focus from interplanetary space flight to planetary surface**
  - **Make Mars the second safest place in the solar system**
  - **Build a "Village" on Mars**
  - **Ensure operational before crew departs**
  - **Use Mars' resources to *reduce mass and cost***
- **Pre-deploy assets for "next" crew available as redundant elements for "current" crew**
- ***Redundancy through "forward deployment" rather than "abort to Earth"***

Mars Reference Mission

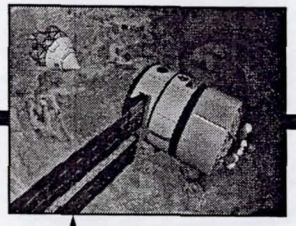
- **Exploration mission planners maintain "Reference Mission"**
- **Represents current "best" strategy for human Mars missions**
- **Purpose is to serve as benchmark against which competing architectures can be measured**
- **Constantly updated as we learn**
- **Probably does not represent the way we will end up going to Mars**

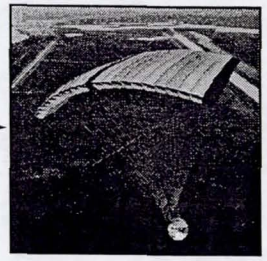
Reference Mission Scenario Overview





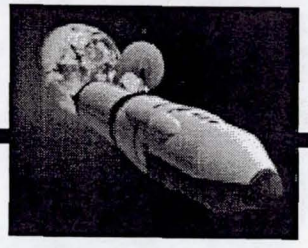
Earth Return Vehicle aerocaptures into Mars orbit



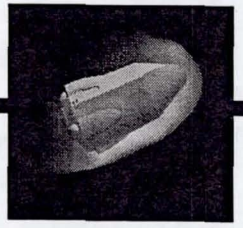


Ascent Vehicle rendezvous with Earth Return Vehicle in Mars Orbit. 130-180 day return trip to Earth ends with direct entry and precision parafoil landing.

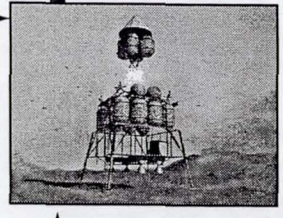
2011 - 2 Cargo Missions Launched



Trans-Mars injection and Cruise

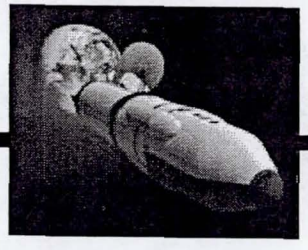


Cargo lander with propellant production plant, power systems, inflatable hab, ascent vehicle lands on Mars

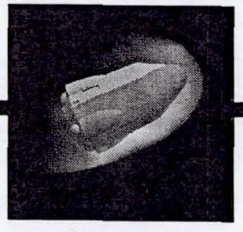


Crew departure. Ascent vehicle uses locally produced methane and LOX.

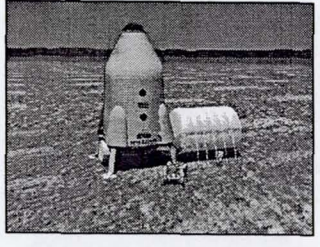
2014 - Crew transit habitat launched



Crew reaches Mars in 130-180 days on fast transit trajectory



Crew Arrival



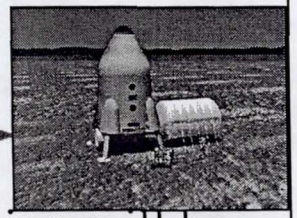
Surface science concentrates on the search for life. Deep drilling, geology and microbiology investigations are supported by both EVA and by surface laboratories.

"Design to the Customer"

- **Low *Cost Rate* To Assure Best Fit to Budget**
- **Deployment can Begin In Early Opportunities (2003+)**
- **Encourage Private Sector Participation by Those *With Best Expertise* in the World, "Turn-Key" Delivery**
- **Encourage International Participation to Provide "Turn-Key" Capabilities At Mars**
- **Use *Existing* Launch Systems**

How Do We Do This?
What is the Plan?

Exploration Roadmap



HUMAN MARS MISSIONS

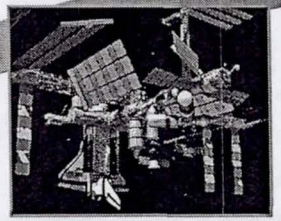
Lunar Science & Technology Test bed??

Human exploration will be driven by our customers

- Possible use of lunar environment for testing Mars hardware and operations
- Lunar sorties conducted as needed

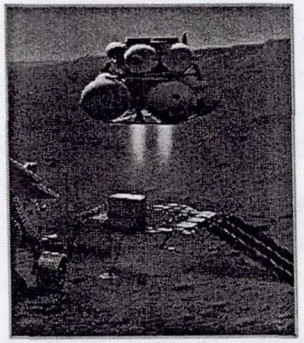
International Space Station

- Human factors research and data
- Long-duration space flight skills & knowledge



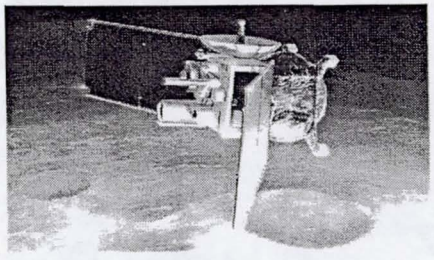
Robotic Precursors

- Multiple robotic missions to Mars are to be flown over the next few opportunities
- These provide an opportunity to demonstrate key technologies applicable to both robotic and human missions

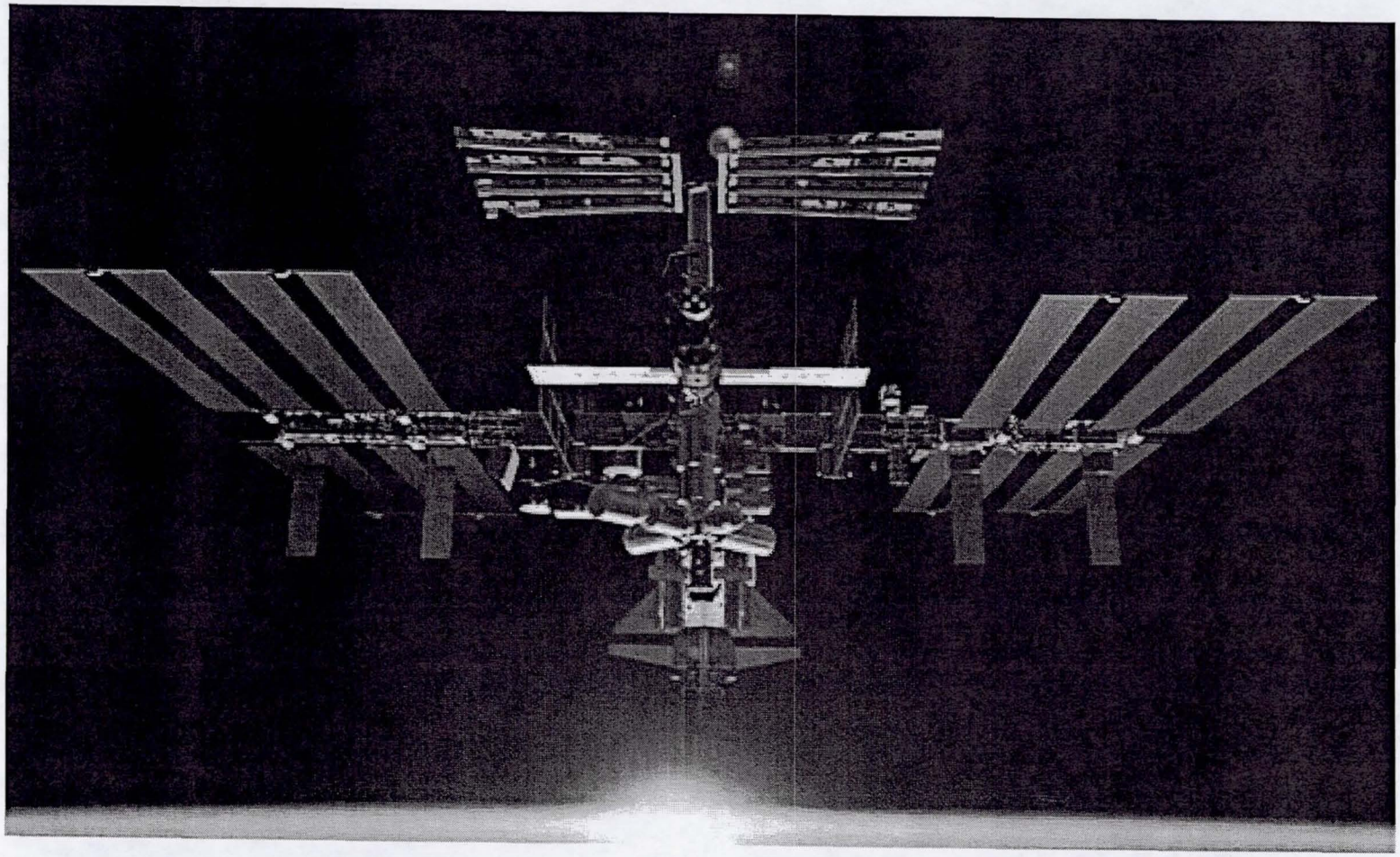


Technology Investments

- Develop Promising Technologies
- Initiate Long-lead Technologies Which Have the Highest Leverage (Cost, Risk, Performance)



But first…



Ad Mars per ISS!

How Will We Go Further Into Space?

International Space Station

To provide...

...a state-of-the-art research facility on which to study gravity's effects on physical, chemical, and biological systems

...a commercial platform for space research and development

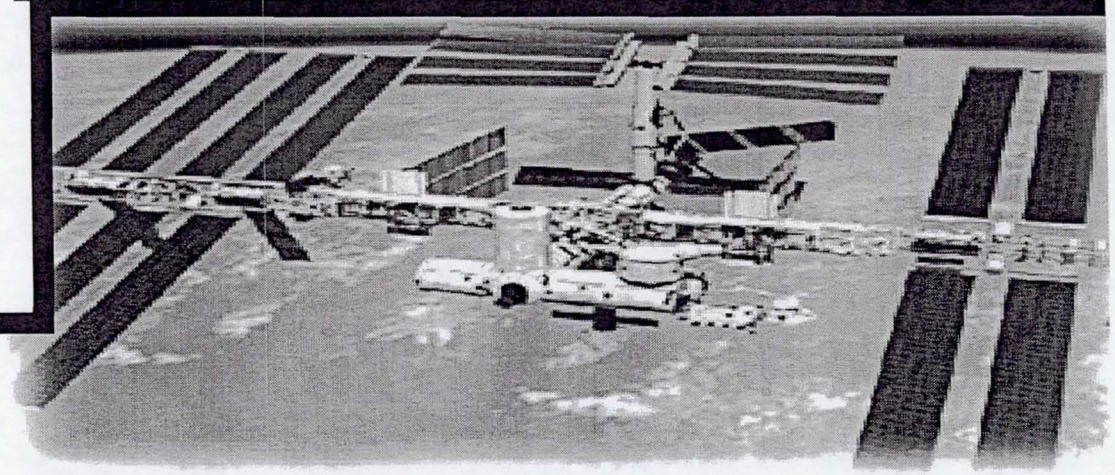
...a test bed for advanced technology for human space exploration

Use space environment...

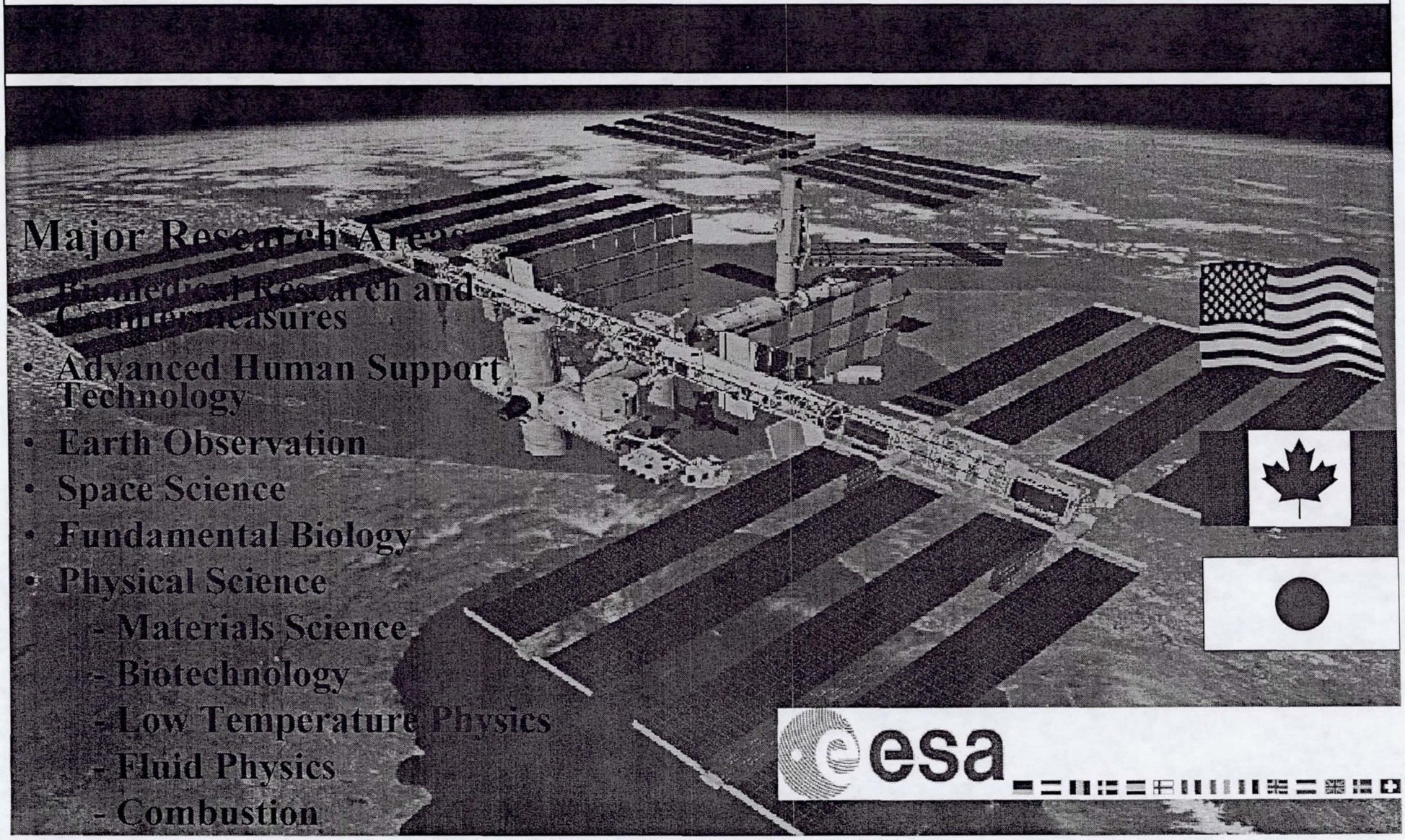
...to advance scientific knowledge

...to live, explore, and work productively in space

...to use the attributes of space to improve products and processes on Earth



What Are the ISS Research Areas?



So, What's Stopping Us From Sending Humans To Mars?

- *We Don't Have "Permission" Yet*
  - *Public Perceptions*
    - Prohibitive Costs
    - Size Of Space Budgets
    - Relative Priorities
  - Reduce Costs (Culturally Constrained)
  - Governmental Priorities For Money
- *What We Can Do*
  - Demonstrate The Value Of Space Exploration To Everyone
  - Find Better Ways To Communicate
  - Involve Our Customers And Stakeholders In The Excitement
  - Become More Active In Policy Making

What Can I Do?

- ***Help to Build the Cultural Expectation That Humans Will Explore Space***
  - ***Work With the Young People***
  - ***Volunteer to Give Programs at Local Schools***
  - ***Volunteer to Speak at Rotary, Other Clubs***
  - ***Work With the Universities Which Feed Your Political Systems***
  - ***Write Articles for Publication***
  - ***Get Involved With the Mass Media***

- ***Work Within the Political System:***
  - ***Get to Know the Important Political Figures***
  - ***Determine What Is Important to the Key People***
  - ***Work in the Campaigns of Key Politicians***
  - ***Show Linkages Between Space Exploration and the Improvement of Life on Earth***

BACKUPS

Scope of Exploration Planning

- ***Planning Must Go Beyond NASA and Include International Partners, Other Agencies, Academia, and the Private Sector***
- ***Planning Approach***
  - Exploration Technology Investments
  - Exploration and Science Partnership: An Integrated Robotic and Human Approach to Exploration
  - "Doable" for Available Money
  - "Sellable" to Customers and Stakeholders

The Time Is Right...

- Explosion of Recent Scientific Discoveries and Technological Advances
- Tremendous Interest in the Search for Origins: Public, Administration, Congress
- Stunning Success of Mars Pathfinder, Global Surveyor, Prospector (Tempered by Losses)
- A Firm, Redefined Robotic Mars Exploration Program Leading to Human Exploration
- Long Duration Space Flight Experience ... International Space Station
- The Understanding that Our Customers Will Determine When And IF We Go.

...For All Of Us To Take the First Small Steps

Our Goal: Position Ourselves and Our Customers to Make A Decision, Within the Next 5-7 Years, on Whether and How to Proceed.

NASA Conditions for Human Mars Exploration (Joe Rothenberg)

- *"Compelling Scientific Or Exploration Rationale*
- *Strong Commercial Potential For High Return*
- *Public Support (Our Customers Must Give Us Permission)*
- *Credible [Meaning Low, Provable] Cost Estimate"*

Credible Costs, Plus Two Of The Remaining Three Conditions Are Mandatory

Mars Reference Mission Issues

- **"Lowest Mass" Assumed Lowest Cost & Risk**
- **Requires Development of Expensive New Launch System**
- **"Three or Four Magnum" Designs Require Full Systems Integration Prior to Launch from Earth**
- **"Spacecraft" versus "Village" Surface Living**
- **Hard to Incorporate International Participation**
- **Hard to Encourage Private Sector Involvement**
- **Everything Deployed in Two Mars Opportunities**
- **Reliability Must be Designed Into Each Critical System (Versus Maintainability and Ample Sparing)**

The Mars Surface Rendezvous Concept

- **Plan the "Village" Analytically, Looking 20-30 Years Ahead**
- **Begin Deployment Early, Based on "Village Plan"**
  - Power System (Small Reactor) Deployed Either by International or Private Sector to Enable Mars Drilling, Establish Power Grid for Humans
  - Mobility Systems From the Automobile Industry, Turnkey Deployment, Paid For Upon Delivery (Guaranteed Market)
  - Communications System From Internationals or Commercial Communications Industry
  - Propellant Plant from Petrochemical Industry
  - Other Utilities (e.g., Heat, Water) From Utility Industry or By-Product of Petrochemical Industry
  - Parts Depots (Use Military Models)
  - Hospital, Kitchen/Galley, Recreation Facility, ETC !
- **Use the World's Existing (and Projected) Commercial Launch Fleet!**

Exploration Strategic Roadmap

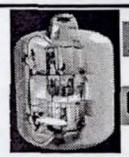
Dates dependent on decision to go & available funding

International Space Station

Assembly Complete

Phase 2 | Phase 3 | Operations Transition | Commercial Utilization

Human Support Technology



BIO-PLEX | TransHab | Lunar Lander | Mars Lander

Biomedical Research & Countermeasures | Radiation Data Analysis | Human Health & Performance Standards

EVA Development | Advanced Spacesuit Technology Development | Next-Generation EVA System | Mars EVA Systems

Space Operations

Communication Initiatives | Commercial Utilization

Lunar and Mars Missions

Surveyor '01 Orbiter

Mars Technology Lander

Mars Sample Return

Technology Readiness

Operational & Technology Tests @ Moon

Human Mars Missions

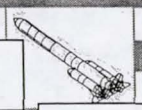
Shuttle Evolution and Space Transportation

Transportation Technology

Shuttle Evolution | Shuttle Upgrades | Liquid Boosters

Crew Transport | CRV

Second Generation RLV | Mars Launcher



HEO

In Situ Resource Utilization

Lunar / Mars Test bed

Mars Flight Demo

Mars Sample Return | Large Scale Propellant Production

Revolutionary Interplanetary Transportation & Power

High Efficiency Propulsion | In-Space Propulsion Downselect | Lunar Propulsion & Power Demo | Full Scale Flight Unit Production

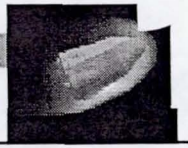
Advanced Space Power

High Speed Aero braking

Mars Aerocapture and Precision Landing Demo

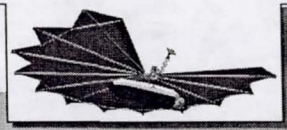
Human Aerocapture (Earth)

Human Aerocapture (Mars)



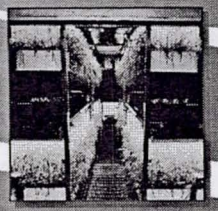
Technologies and Designs to Reduce RISKS

RISK REDUCTION THROUGH TECHNOLOGY



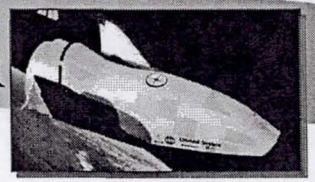
Solar Electric Propulsion

Advanced Life Support



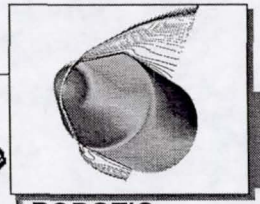
BIO-PLEX

CREW TRANSFER

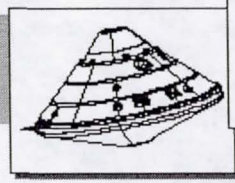


TEST AND DEMONSTRATION FLIGHTS

LOW EARTH ORBIT

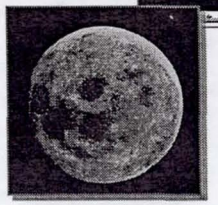


AEROCAPTURE

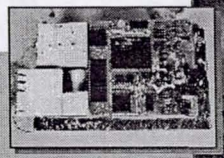


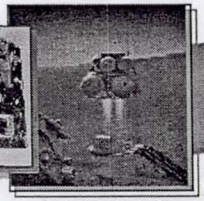
ROBOTIC MISSION TESTS

ASTEROIDS



In Situ Resource Utilization

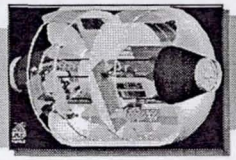




ROBOTIC MISSION TESTS

MOON

Lightweight Structures and Systems



MINIATURIZED AVIONICS

LIBRATION POINTS

INFLATABLES

Heavy Lift ?

80 METRIC TONS TO LEO